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TECHNICAL REPORT NO. 79-16

SPECIAL DATA COLLECTION SYSTEM
FINAL REPORT, PROJECT T/4703
CONTRACT F08606-78-C-0011

OCTOBER 1977 THROUGH NOVEMBER 1979

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TELEDYNE
GEOTECH

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SPECIAL DATA COLLECTION SYSTEM
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by

John R. Sherwin
and
George C. Kraus

Sponsored by

Advanced Research Projects Agency
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The work performed under Project T/4703, Special Data Collection Systems, during the period from October 1977 through November 1979 is described. The program is an extension of the program which began in 1973 under Contract FO8606-74-C-0013.

During this program, approximately 90 team-months of operation were completed using all or selected parts of eight SDCS units at 12 different sites. The program began with four stations continuing operations from the previous contract, at Tatum Dome, MS (TO-MS), Gasbuggy, NM (GB-NM), Houlton, ME (HN-ME), and

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20. ABSTRACT, Continued

Red Lake, Ontario (RK–ON). During late 1977 and early 1978, additional stations were placed in operation at Island Falls, ME (IF-ME), Rio Blanco, CO (RB-CO), and Gold Meadows, NV (GQ-NV). The data collected at these sites were used by other programs to investigate potential signal anomalies near the sites of previous underground explosions. Data collection for this experiment continued at four of these sites until late August 1978; three of the stations terminated operations during the interim period. By 29 August, all operations except that at RB-CO had been terminated.

In late 1978, data collection began for a related experiment at RB-CO, Oak Spring Butte, NV (OB4NV), Rulison, CO (RU-CO), and Battle Mountain, NV (BJ-NV). In this experiment, data were to be investigated to determine the effects of a high heat-flow area on seismic signals. Data collection operations at these four sites were terminated in March 1979.

At all of these sites except HN-ME, standard SDCS instrumentation was used; i.e., seismometers in surface vaults with recording and related equipment. In addition, short-period data only were collected at all sites except HN-ME, RK-ON, and BJ-NV, where both short- and long-period data were collected. At HN-ME, the KS36000 was used to collect high quality data. Finally, selected sites utilized digital recorders in addition to the standard analog recorders.

A special project to collect high-frequency data at a site near McKinney, Texas, was begun in June, 1978. In the first phase of operations, data were collected from both the KS36000 vertical and a standard vertical instrument in the high-frequency passband. These data were analyzed at Southern Methodist University (SMU) to determine whether the KS36000 operates properly at this frequency. Phase two, which began in mid-September 1978 and continued through January 1979, collected one channel of high-frequency data and three channels of intermediate period data from the KS36000 to determine the potential usefulness of such seismographs in detection of events at relatively close distances up to 650 km. Data analysis and reports of results were done by SMU personnel under a separate contract.

In another special program, completed during the period from September 1978 through January 1979, methods for reducing the cost of short-period borehole installations were investigated. First, a recently developed, low-cost seismometer was evaluated prior to developing a borehole package for the unit. This study indicated that an existing, conventionally designed seismometer was better suited for the application. A second cost reducing technique investigated was the use of shallow, plastic-cased boreholes. It was found that shallow (15 m), plastic-cased holes were inexpensive and did not degrade instrument operation. However, it was determined that the plastic casing required was easily damaged during its installation in the relatively small diameter open borehole which the low-cost requirement imposed. Results of this study were published in a separate technical report.

A detailed site selection manual was prepared in July 1979 under another special program. This manual was delivered to the Project Office as required.

Finally, the KS36000 and other supporting SDCS instrumentation were operated at Cumberland Plateau Observatory, Tennessee (CPO) from March through May 1979. The data collected were to be used for evaluating the Sandia Model I National Seismic Station then being tested at CPO. The MCK operation was continued during this time to support the various tests.

All operations were terminated 31 June 1979, and all equipment was returned to Garland, Texas for refurbishing and storage. At the close of the contract, all equipment was in storage as required.

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SPECIAL DATA COLLECTION SYSTEMS
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OCTOBER 1977 THROUGH NOVEMBER 1979

1. INTRODUCTION

The Special Data Collection System (SDCS) program~~, Project T/4703,~~ is an extension of work begun under the Long-Range Seismic Measurements (LRSM) program in 1960. The work is directed primarily toward collection of high quality seismic data for the development of seismic techniques necessary to detect and identify underground nuclear explosions. In addition, the program also involves related special studies such as instrumentation development and special field studies ~~utilizing~~ the equipment and capabilities of the program.

This report describes the work performed under the SDCS program from October 1977 through November 1979 and is submitted in accordance with sequence A004 of the Contract Data Requirements List. This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by AFTAC/VSC, Patrick AFB, Florida 32925, under Contract No. F08606-78-C-0011.

2. FIELD OPERATIONS

2.1 GENERAL

The basic instrumentation for the SDCS program consists of eleven units of the Portable Seismograph System, Geotech Model 19282. This system includes three short-period seismometers (Geotech Model 18300) capable of being operated in the vertical or horizontal mode, a long-period vertical seismometer (Geotech Models 7505 or 28280), and two long-period horizontal seismometers (Geotech Models 8700 or 28700) with associated amplifiers and filters for response shaping with recording on slow-speed FM magnetic tape; also included are necessary timing, calibration and support equipment. The system is designed for quick deployment by a qualified electronic technician and is capable of recording laboratory quality data. Other instrumentation assigned to the program inventory provides versatility and increased operating capability of the basic system. Examples of such instrumentation include three Model 36000 Borehole Seismograph Systems (KS36000) and five digital data recording systems.

During this report period, SDCS units collected data at the sites and with the instrumentation shown in figure 1. The TQ-MS, GB-NM, RB-CO, OB4NV, and RV-CO sites are located near the sites of previous underground nuclear explosions.

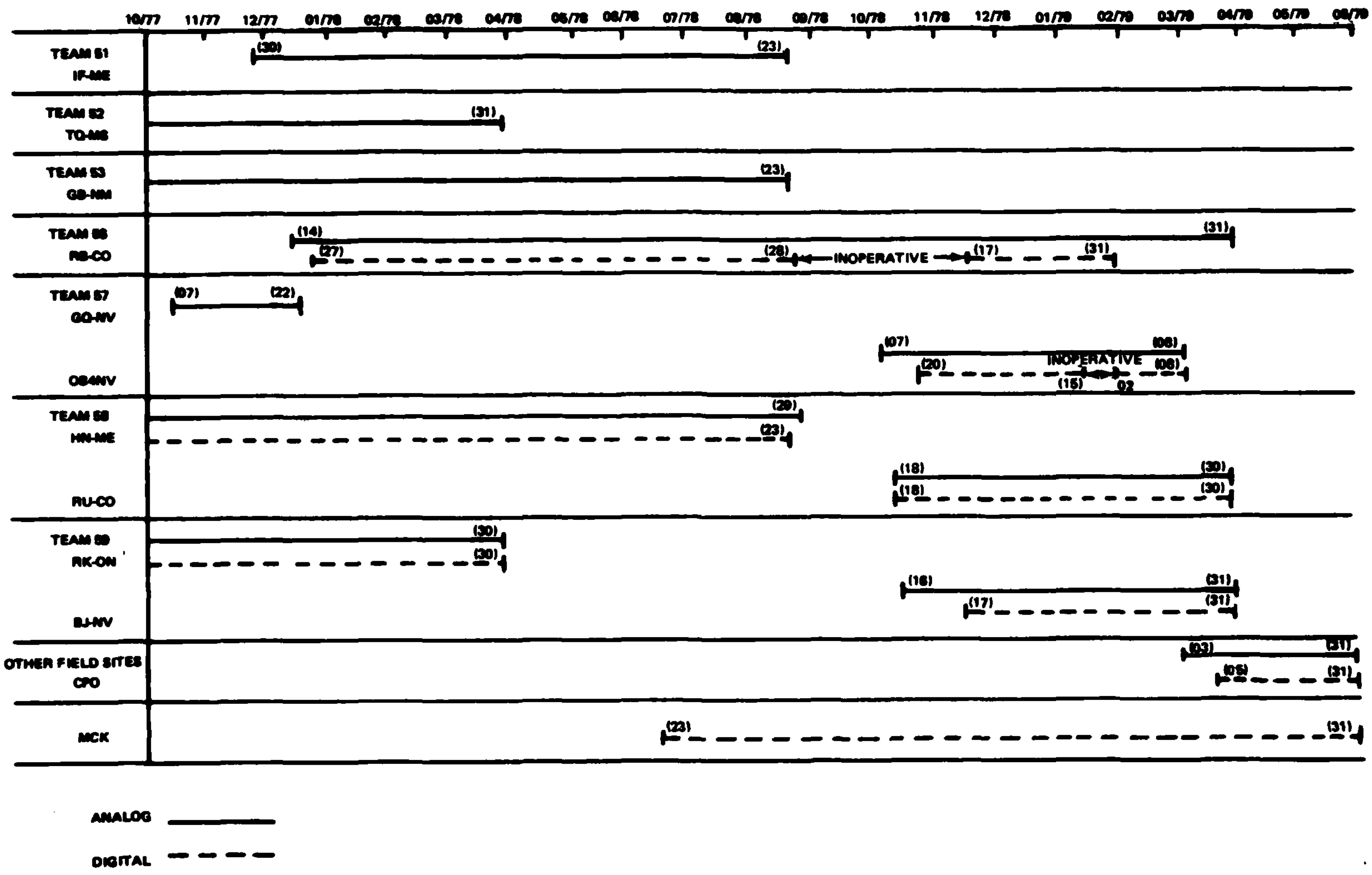

FIGURE 1. OPERATIONAL PERIODS FOR SDCS SITES – OCTOBER 1977 THROUGH NOVEMBER 1979

Data were recorded to be used in studies of incoming teleseismic signals which would better explain the anomalies caused by local geology on explosion-generated signals and other problems related to the identification of underground nuclear explosions. The BJ-NV data were recorded for use in similar studies to evaluate the effects on seismic signals of the high heat flow around the Battle Mountain area of Northern Nevada. The purpose of the MCK operation was first to evaluate the operation of the KS36000 at higher frequencies (1 to 15 Hz), and second to determine the potential usefulness of high-frequency and intermediate period seismographs in the detection of near-regional seismic signals (distances to 650 km). Finally, the CPO deployment was to collect data from a KS36000 system for comparison with, and detailed evaluation of, data from the Sandia Corporation Model I National Seismic Station. The remaining SDCS units were maintained in storage at Geotech's Garland, Texas, facility.

In all cases, data collection and data quality verification tasks were the responsibility of the SDCS program, and analysis tasks were assigned to other organizations as directed by the Project Office.

2.2 FIELD LOCATIONS

The function of each SDCS is to record high quality seismic data. However, each location differs from the others in the equipment utilized, the data recorded, and the environmental conditions under which it is operated. Figure 2 is a map showing the locations of the sites occupied during the October 1977 through November 1979 period, and table 1 lists pertinent data for each site. The following paragraphs summarize the site activities at each SDCS location during this report period.

2.2.1 Team 51, Island Falls, Maine (IF-ME)

The Island Falls, Maine (IF-ME) site is located approximately 23 km (14.5 miles) southwest of the Houlton, Maine (HN-ME) site. The site is located on an intrusive igneous (granite) outcrop. This bedrock is more competent than the metamorphic slates at the HN-ME site, and data were collected here for comparison with the HN-ME data. Analog recording of three component short-period data began on 30 November 1977 and continued virtually uninterrupted until recording was terminated on 23 August 1978. Data were recorded in the analog mode only as no commercial power was available to power a digital recorder.

The site was operated by the HN-ME operator with no loss in operational effectiveness. During the winter months (mid-December 1977 to the end of March 1978), site access at IF-ME was possible only by snow-mobile or other snow vehicles. The severe weather conditions resulted in few periods of lost data with the most data outage being caused by heater failure in the instrument building, allowing the temperature of the recorded environment to fall below operating limits.

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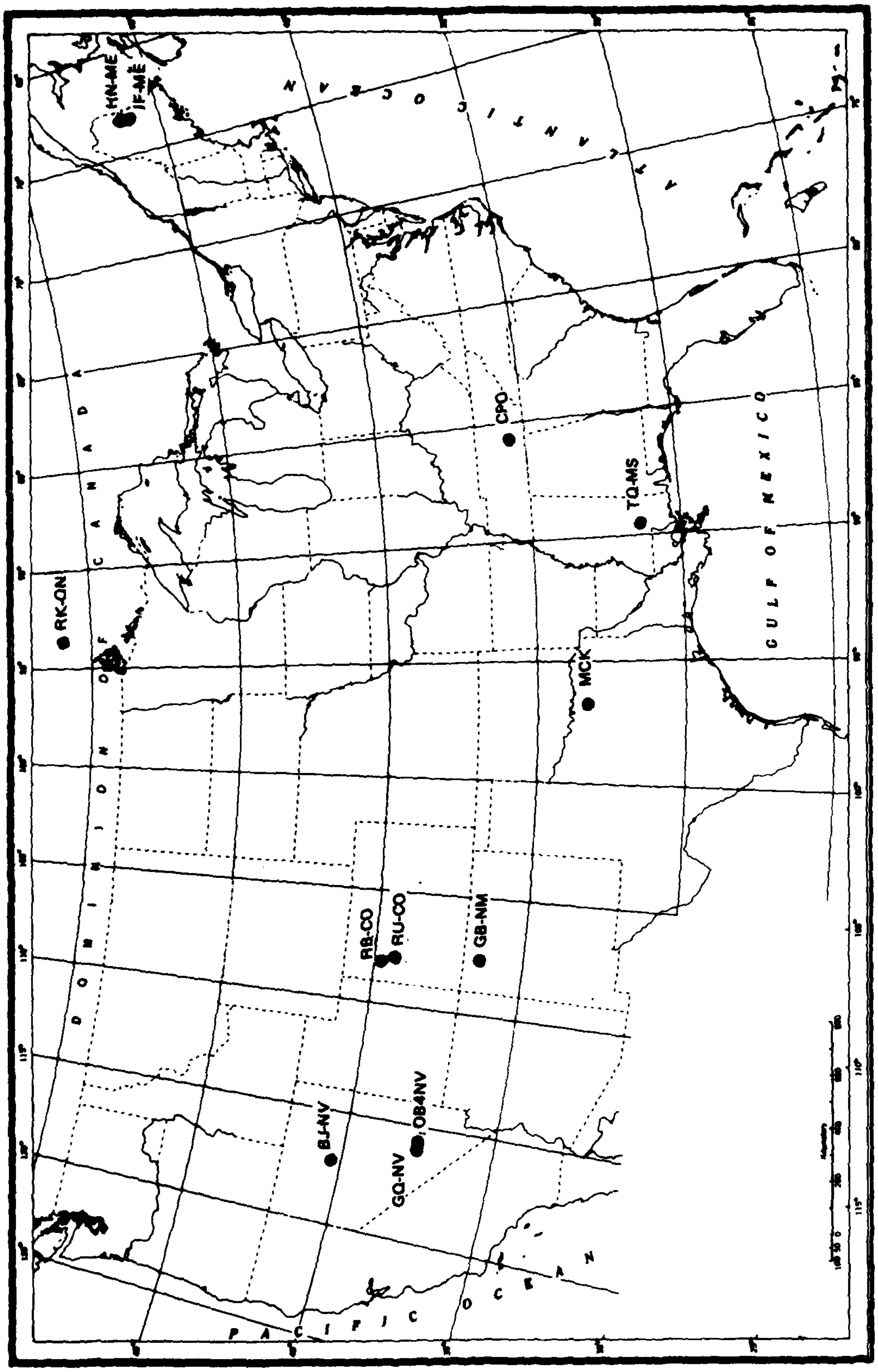


FIGURE 2. SITES OCCUPIED DURING OCTOBER 1977 THROUGH NOVEMBER 1979

TEAM NO.	SITE DESIGNATION	COORDINATES	ELEVATION	SEISMOMETER DEPTH	SEISMOMETERS	MA RE
51	ISLAND FALLS, MAINE (IF-ME)	46° 01' 39" N 68° 12' 28" W	232 METERS (760 FEET)	SURFACE	GEOTECH MODEL 18300 (SP)	GEOTE
52	TATUM DOME, MISSISSIPPI (TQ-MS)	31° 07' 58" N 89° 34' 16" W	130 METERS (427 FEET)	SURFACE 285 METERS (934 FEET)	GEOTECH 18300 (SP) GEOTECH 23900 (SP)	GEOTE
53	GAS BUGGY, NEW MEXICO (GB-NM)	36° 41' 13" N 107° 13' 34" W	2164 METERS (7100 FEET)	SURFACE	GEOTECH 18300 (SP)	GEOTE
56	RIO BLANCO, COLORADO (RB-CO)	39° 48' 46" N 108° 21' 21" W	1996 METERS (6550 FEET)	SURFACE	GEOTECH MODEL 18300 (SP)	GEOT MODE
57	GOLD MEADOWS, NEVADA (GQ-NV)	37° 13' 45" N 116° 12' 20" W	2057 METERS (6750 FEET)	SURFACE	GEOTECH MODEL 18300 (SP)	GEOT
	OAK SPRINGS BUTTE 4, NEVADA (OB4NV)	37° 13' 10" N 116° 03' 41" W	1524 METERS (5000 FEET)	SURFACE	GEOTECH MODEL 18300 (SP)	GEOT MODE
58	HOULTON, MAINE (HN-ME)	46° 09' 43" N 67° 59' 09" W	213 METERS (699 FEET)	SURFACE 34 METERS (112 FEET)	GEOTECH 18300 (SP) GEOTECH KS 36000 (SP&LP)	GEOT MOD
	RULISON, COLORADO (RU-CO)	39° 26' 52" W 107° 58' 39" W	1914 METERS (6280 FEET)	SURFACE	GEOTECH MODEL 18300	GEOT MOD
59	RED LAKE, ONTARIO (RK-ON)	50° 50' 20' N 93° 40' 20" W	336 METERS (1102 FEET)	SURFACE (BUNKER)	GEOTECH 18300 (SP) GEOTECH 28280 (LPZ GEOTECH 28700 (LPH)	GEOT MOD
	BATTLE MOUNTAIN, NEVADA (BJ-NV)	40° 25' 53" N 117° 14' 18" W	1512 METERS (4960 FEET)	SURFACE (MINE)	GEOTECH 18300 (SP) GEOTECH 28280 (LPZ) GEOTECH 28700 (LPH)	GEO MO
--	MCKINNEY, TEXAS (MCK)	33° 14' 56" N 96° 39' 07" W	210 METER (690 FEET)	152 METERS (500 FEET) SURFACE)	GEOTECH 18300 (SP) GEOTECH 28280 (LPZ) GEOTECH 28700 (LPH)	GEO
--	CUMBERLAND PLATEAU OBSERVATORY TENNESSEE (CPO)	35° 36' 01" N 85° 34' 08" W	567 METERS (1860 FEET)	100 METERS (320 FEET)	GEOTECH KS 36000 (SP & LP)	GEO MO

TABLE 1. SITE INFORMATION AND EQUIPMENT FOR SDCS DEPLOYMENT DURING THE PERIOD FROM OCTOBER 1977 THROUGH NOVEMBER 1979

ON	SEISMOMETER DEPTH	SEISMOMETERS	MAGNETIC TAPE RECORDERS	DATA RECORDED	DATA RECORDING RATES
ERS T)	SURFACE	GEOTECH MODEL 18300 (SP)	GEOTECH MODEL 19429	SPZ,SPN, SPE	.03 IPS (ANALOG)
ERS T)	SURFACE 285 METERS (934 FEET)	GEOTECH 18300 (SP) GEOTECH 23900 (SP)	GEOTECH MODEL 19429	SPZ, SPN, SPE SPZDH	.03 IPS (ANALOG) .03 IPS (ANALOG)
TERS ET)	SURFACE	GEOTECH 18300 (SP)	GEOTECH MODEL 19429	SPZ, SPN, SPE	.03 IPS (ANALOG)
TERS ET)	SURFACE	GEOTECH MODEL 18300 (SP)	GEOTECH MODEL 19429 MODEL 43419	SPZ, SPN, SPE SPZ, SPN, SPE	.03 IPS (ANALOG) 20 SPS (DIGITAL)
TERS ET)	SURFACE	GEOTECH MODEL 18300 (SP)	GEOTECH MODEL 19429	SPZ, SPN, SPE	.03 IPS (ANALOG)
TERS ET)	SURFACE	GEOTECH MODEL 18300 (SP)	GEOTECH MODEL 19429 MODEL 43319	SPZ, SPN, SPE SPZ, SPN, SPE	.03 IPS (ANALOG 20 SPS (DIGITAL)
ERS ET)	SURFACE 34 METERS (112 FEET)	GEOTECH 18300 (SP) GEOTECH KS 36000 (SP& LP)	GEOTECH MODEL 19429 MODEL 43419	SPZ, SPN, SPE, SPZ SURF LPZ, LPN, LPE SPZ, SPN, SPE, SPZ SURF LPZ, LPN, LPE	.03 IPS (ANALOG) 20 SPS } DIGITAL 1 SPS } DIGITAL
TERS ET)	SURFACE	GEOTECH MODEL 18300	GEOTECH MODEL 19429 MODEL 43419	SPZ, SPN, SPE SPZ, SPN,SPE	.03 IPS (ANALOG) 20 SPS (DIGITAL)
RS ET)	SURFACE (BUNKER)	GEOTECH 18300 (SP) GEOTECH 28280 (LPZ GEOTECH 28700 (LPH)	GEOTECH MODEL 19429 MODEL 43419	SPZ, SPN, SPE LPZ, LPN, LPE SPZ, SPN, SPE LPZ, LPN, LPE	.03 IPS (ANALOG 20 SPS (DIGITAL) 1 SPS (DIGITAL)
TERS ET)	SURFACE (MINE)	GEOTECH 18300 (SP) GEOTECH 28280 (LPZ) GEOTECH 28700 (LPH)	GEOTECH MODEL 19429 MODEL 43419	SPZ, SPN, SPE LPZ, LPN, LPE SPZ, SPN, SPE LPZ, LPN, LPE	.03 IPS (ANALOG) 20 SPS } DIGITAL 1 SPS } DIGITAL
R T)	152 METERS (500 FEET) SURFACE)	GEOTECH 18300 (SP) GEOTECH 28280 (LPZ) GEOTECH 28700 (LPH)	GEOTECH MODEL 43419	HFZ, HFZ-S HFZ AND IPZ, IPN, IPE	60 SPS (DIGITAL) 60 SPS } DIGITAL 6 SPS } DIGITAL
RS T)	100 METERS (320 FEET)	GEOTECH KS 36000 (SP & LP)	GEOTECH MODEL 19429 MODEL 43419	SPZ, SPN, SPE LPZ, LPN, LPE SPZ, SPN, SPE LPZ, LPN,LPE	.03 IPS } ANALOG .03 IPS } ANALOG 20 SPS } DIGITAL 1 SPS } DIGITAL

2

2.2.2 Team 52, Tatum Dome, Mississippi (TQ-MS)

The Tatum Dome, Mississippi (TQ-MS) site is located near the Surface Ground Zero (SGZ) of Projects DRIBBLE and MIRACLE PLAY conducted in the Tatum Salt Dome. The site was 520 meters (1700 feet) SSW of the SALMON detonation SGZ. Routine recording of three component short-period data continued from the start of this report period until 31 March 1978 when the station was closed. In December 1977, a Model 23900 short-period vertical borehole seismometer was installed in Well E-7 at a depth of 285 meters (934 feet). At this depth, the seismometer was in the anhydrite caprock of the Tatum Salt Dome.

There were no unusual operational problems, but the lack of competent bedrock and the abundance of tall trees in the area combined to keep operating magnifications low. Heavy rains flooding the vaults on several occasions were the major operational problems. Data were recorded in the analog mode only as no commercial power was available.

The operation of the borehole instrument was acceptable; but cross talk between the data and calibration lines in the downhole cable resulted in unreliable calibrations, especially at the higher frequencies. During installation, the holelock would not actuate, and the instrument was therefore operated resting on the bottom of the hole. Overall, operation of the borehole instrument resulted in the reduction of wind noise by 6 to 12 dB (as compared to the surface data), but there was little apparent improvement in detection capability.

2.2.3 Team 53, Gasbuggy, New Mexico (GB-NM)

The location of the Gasbuggy, New Mexico (GB-NM) site is near the SGZ of the GASBUGGY experiment in northern New Mexico. The recording of three component short-period data continued routine from 29 May 1977 until the station was closed on 23 August 1978. Data were recorded in the analog mode only as commercial power for a digital recorder was unavailable.

The major problem areas were site access during February and March of 1978 when the dirt access roads became impassable due to heavy rain and snow. Data were lost only when the operator could not reach the site to resupply the propane for the thermoelectric generators (TEGs).

2.2.4 Team 56, Rio Blanco, Colorado (RB-CO)

The Rio Blanco, Colorado (RB-CO), site is located in western Colorado near the SGZ of the Project RIO BLANCO detonations. Site selection and leasing were completed in November 1977, and site preparation was completed in early December. Site operations were begun on 14 December 1977 with the analog recording of three component short-period data. Digital recording was delayed until 27 December 1977 because the digital system failed during system checkout, and no spare parts were readily available.

Analog data recording continued virtually uninterrupted until the station was closed on 31 March 1979. Digital data recording was interrupted from 28 August to 01 December 1978 due to extensive damage caused by a lightning strike and the unavailability of spare parts. The digital recorder was removed from the site on 31 January 1979 to be used at the Cumberland Plateau Observatory (CPO). On several occasions during the winter months, site access was delayed or was impossible due to hazardous driving conditions. Some digital data loss was attributed to access problems, but the analog data recording was uninterrupted.

The site was closed on 31 March; and, with the approval of government property personnel, the temporary building was given to the landowner in lieu of having it moved. The commercial power line servicing the site area was scheduled to be removed following our departure.

2.2.5 Team 57

2.2.5.1 Gold Meadows, Nevada (GQ-NV)

The Gold Meadows, Nevada (GQ-NV) site is located on a quartz monzonite stock on Rainier Mesa on the Nevada Test Site (NTS). The location of the site on the stock provided a similar bedrock to the Climax stock on which the Oak Springs Butte, Nevada (OB2NV, OB3NV, and OB4NV), sites were located. The data from these sites were to be used in comparison studies.

The GQ-NV site was occupied on 01 October 1977, and the recording of three component short-period analog data began on 07 October 1977. Thermoelectric generators (TEGs) were used for power as no commercial power was available at this remote location. The site was operated routinely until early December 1977 when snowfalls on Rainier Mesa made access hazardous. By late December 1977, access was impossible by ordinary means; and, at the direction of NTS personnel, the site was abandoned until access could be accomplished.

2.2.5.2 Oak Springs Butte 4, Nevada (OB4NV)

The Team 57 equipment was moved from Gold Meadows, Nevada (GQ-NV), to Oak Springs Butte 4, Nevada (OB4NV), during September 1978. Additional equipment was added to enable the three component short-period data to be recorded in both analog and digital modes. The OB4NV location is an alternate site to OB2NV which was occupied previously, but cultural activity in the immediate area made it unsuitable for use. The OB4NV site is still on the Climax stock but as far away as practical from the noise source.

Analog recording began on 07 October 1978 and continued virtually uninterrupted until 08 March 1979 when the station was closed. The only interruptions in the analog recording were due to activity on the NTS. Digital data recording began on 20 October 1978 and was continuous, except for NTS activity until 15 January 1979 when a malfunction in the digital tape deck occurred. The digital recorder was inoperative until 02 February 1979 when the proper replacement parts were installed.

2.2.6 Team 58

2.2.6.1 Houlton, Maine (HN-ME)

Site operations at Houlton, Maine (HN-ME) continued uninterrupted from the beginning of the report until the station was closed on 29 August 1978 (operations under this deployment began in March 1975). The recording of three component short-period and three component long-period data from a KS36000 borehole seismometer was accomplished in both analog and digital formats. Digital recording was terminated on 23 August, but analog recording continued until the station was closed. The HN-ME site operator was also responsible for site operations at IF-ME and, in spite of hazardous weather conditions during the winter months, no significant amounts of data were lost at either site.

The site was left with the recorder building intact, the borehole dry and locked, and the surface vault covered. Under the terms of the lease agreement, Teledyne Geotech retains the option to reoccupy this site until 1986 when all rights to the borehole revert to the landowner. Lease fees are payable only during those periods that the site is occupied. When the site was closed, Weston Observatory of Boston College requested permission to use the building and surface vault to install seismic equipment as part of a large monitoring network. The landowner was notified of this request and was informed that Weston Observatory personnel were to make separate arrangements with her.

All of the Team 58 equipment was returned to Teledyne Geotech's Garland facility in early September 1978 and reconfigured to a standard system. All of the special equipment associated with the KS36000 such as filters, amplifiers and special wiring were removed from Team 58 but kept intact. The special equipment was subsequently used for the CPO operation.

2.2.6.2 Rulison, Colorado (RU-CO)

Team 58 was deployed to the Rulison area in western Colorado in October 1978. Three component short-period data were recorded in analog and digital formats from the site near the SGZ of Project RULISON detonation. Data recording continued from 18 October 1978 until the station was closed on 30 March 1979 with no data loss.

Prior to deployment to RU-CO, a small, used camper trailer was purchased for use as a field operations shelter in lieu of purchasing a temporary building on site. The use of the small camper trailer was very satisfactory as system transportation, installation, and shutdown was easier than had been in the past. During the installation, the site operator was assisted by an airman from the U. S. Air Force Academy (USAFA) at Colorado Springs, Colorado. During installation, he was instructed in installation, calibration, and operation techniques for seismic instrumentation. The training was conducted on site on a noninterference basis with the approval of the Project Office to assist Academy personnel in the planned installation of a seimsic research station at the USAFA.

Site access was difficult during the winter due to heavy snow accumulations, but no data were lost. The railroad approximately 4 km north of the site in the Colorado River valley is the primary source of noise at this location.

2.2.7 Team 59

2.2.7.1 Red Lake, Ontario (RK-ON)

Site operations at Red Lake were terminated on 30 March 1978 after three years of continuous operation. The recording of three component short-period and three component long-period data in both analog and digital formats continued virtually uninterrupted until the station was closed.

The major equipment problem at RK-ON concerned power generator malfunctions and the difficulty in obtaining adequate replacement parts. During one period, both units were in for repair, and a rental unit had to be used. Although the generators were the major source of problems, they are considered to be reliable units. They supplied all station power continually from March 1975 until the station was closed.

Routine operational schedules were interrupted during the winter months due to heavy snowfall delaying operator arrival on site. In most cases, analog data recording continued uninterrupted while digital data recording stopped when the tape supply ran out.

The Red Lake site had been occupied on several occasions since 1963 when the site was first installed. After each operational period, the site lease was kept current and the vaults and bunker housing the vaults left intact. However, with expiration of the operating agreement with the Canadian government making further use of this site highly unlikely, the site was restored to its original condition following our departure. The bunker, vaults, generator shelter and pads, fuel tanks, and operating shelter were removed and the area was graded, cleaned and reseeded. The clean-up work was subcontracted to local personnel as heavy snow cover prevented the completion of the work prior to our departure. In June 1978, the Ministry of Natural Resources of the Province of Ontario informed us that the work had been satisfactorily completed and that all the terms of our lease had been satisfied.

2.2.7.2 Battle Mountain, Nevada (BJ-NV)

The BJ-NV site is a small prospect mine in northern Nevada which is used by the Sandia Corporation and the University of Nevada in Reno for seismic instrumentation. The use of the site was coordinated through Mr. Keith Priestly of the University of Nevada in Reno, Nevada.

The analog recording of three-component short-period and of three-component long-period data began on 16 October 1978 and continued uninterrupted until the station was closed on 31 March 1979. Digital recording at BJ-NV was not started until 17 November 1978 due to a delay in receiving a replacement analog-to-digital converter board from the manufacturer to be used in the Kinemetrics Data Recording System.

As at RU-CO, a small camper trailer was bought with contract funds to be used as an equipment shelter. The unit was adequate as a shelter even in the coldest weather and made site set-up, tear-down, and transportation much easier than it had been previously. No major site access problems were experienced although heavy snow delayed the arrival of the operator on site on several occasions.

2.2.8 McKinney, Texas (MCK)

A cooperative effort with Southern Methodist University (SMU) to collect data at the McKinney, Texas, test site continued throughout the period. Data were recorded on digital tape only from both surface and borehole seismometers in high frequency and intermediate frequency bandpasses. Some site access difficulty was encountered after periods of heavy rain, and some recording difficulty was associated with digital tape recorder shutdown due to power failures.

The system configuration was changed several times during this period to respond to the various requirements of the data processing at SMU. During October, November, and December 1978, narrow band high frequency (HFZ) and intermediate period (IFZ, IFN, and IFE) seismographs were recorded from the KS36000. From January through late March 1979, the surface high-frequency seismograph (HFZ-S) was substituted for the intermediate period channels, and both seismographs were operated in a wider band to include more data at 1 to 2 Hz. Finally, intermediate period operation was resumed, along with the wide band HFZ, in late March. Data recording continued until 31 May when routine operations were discontinued. The equipment was left on site to be used to support data gathering activities under an Air Force Office of Scientific Research (AFOSR) contract later in the year.

2.2.9 Cumberland Plateau Observatory, Tennessee (CPO)

The SDCS unit configured to record data from a KS36000 seismometer was deployed to CPO near McMinnville, Tennessee, to support the program of evaluating the Sandia Model I NSS system. The system arrived on site on 26 February 1979. The digital recording of special test data from near the surface was accomplished on 01/02 March 1979, but subsequent data processing procedures revealed a problem with the digital recorder that was not detectable in the field. After several attempts to repair the unit in the field, the digital recorder was replaced in April 1979 with the unit that had been recently returned from OB4NV. Digital recording was also interrupted from 17 to 23 May due to a failure in the Pertec tape deck electronics. The recording of data from depth on the analog recorder began on 03 March and continued virtually uninterrupted until the station was closed on 31 May 1979. On 29 and 30 May, the special high-frequency test was repeated as planned and satisfactorily completed. The equipment was returned to Garland, Texas, checked out, and stored in the warehouse. The system, which is configured to use the KS36000 borehole seismometer, will be kept intact for possible future deployment.

2.3 OPERATING CHARACTERISTICS OF FIELD SYSTEMS

The overall philosophy of the SDCS program is to operate systems with near-identical characteristics in order to allow easier comparison of data from different locations. To assure this, operators routinely check all system parameters to assure that they are within specifications and make corrections as required. Of course, special operating configurations require deviations from this philosophy in order to collect the data required for the particular study. In the following paragraphs, operating parameters for the various SDCS field sites are discussed.

2.3.1 Responses of the Various Systems

The theoretical amplitude and phase response of the standard SDCS short-period and long-period systems of the Portable Seismograph System, Models 19282 and 19282A, are shown in figures 3 and 4, respectively. These curves are applicable for SP data collected at all sites except MCK, CPO, and HN-ME and for the LP data collected at BJ-NV, the only surface LP station operated during this period. Figures 5 and 6 show the responses of the KS36000 systems used at HN-ME and at CPO. The dotted line on figure 5 is the SP system response obtained by modifying the filter in order to collect high-frequency data in a brief test at CPO. The discontinuity in the LP phase response of figure 6 is due to the 6-second notch filter used in the system. Figure 7 shows the amplitude response of the high-frequency vertical (HFZ) channels at the MCK site. The broader response used after 19 January 1979 was developed at the request of the data analysts at SMU to allow easier evaluation of the HF seismographs. In all of the responses, the curves show the output of the seismograph to a constant displacement input at various frequencies. Figure 8, on the other hand, shows the response of the intermediate-period (IP) seismograph to a constant velocity input.

Note that these responses do not include the effects of any filters in the analog playback systems if used. Also, the response of the anti-alias filters in the digital recorders is not included. For all digital recording, the anti-alias filters are set to one-fourth of the sampling frequency, and the filters are six-pole Butterworth type. For normal operation, the SP anti-alias filters are set at 5 Hz, and the LP units operate at 0.25 Hz.

2.3.2 Operating Characteristics of the Digital Recording System, Model 43419

The Digital Recording System, Model 43419, is configured to record both SP and LP data from the SDCS units. For normal operation, the system records four channels of SP data at 20 samples per second (sps) and four channels of LP data at 1 sps in a special interrupt mode; anti-alias filters are set at one-fourth of the sampling rate, or 5 Hz and 0.25 Hz for SP and LP channels, respectively. In this mode, 80 SP samples are accumulated in a buffer during each one-second interval, followed by the four LP samples; the buffer capacity is such that it is filled with header information and data every 12 seconds, after which a 2048 byte data record is written on a one-half inch, 800 bpi, IBM compatible magnetic tape. The tape format in the standard mode is shown in figure 9. This interrupt format was used for all routine SDCS operations whether LP instrumentation was installed at the station or not.

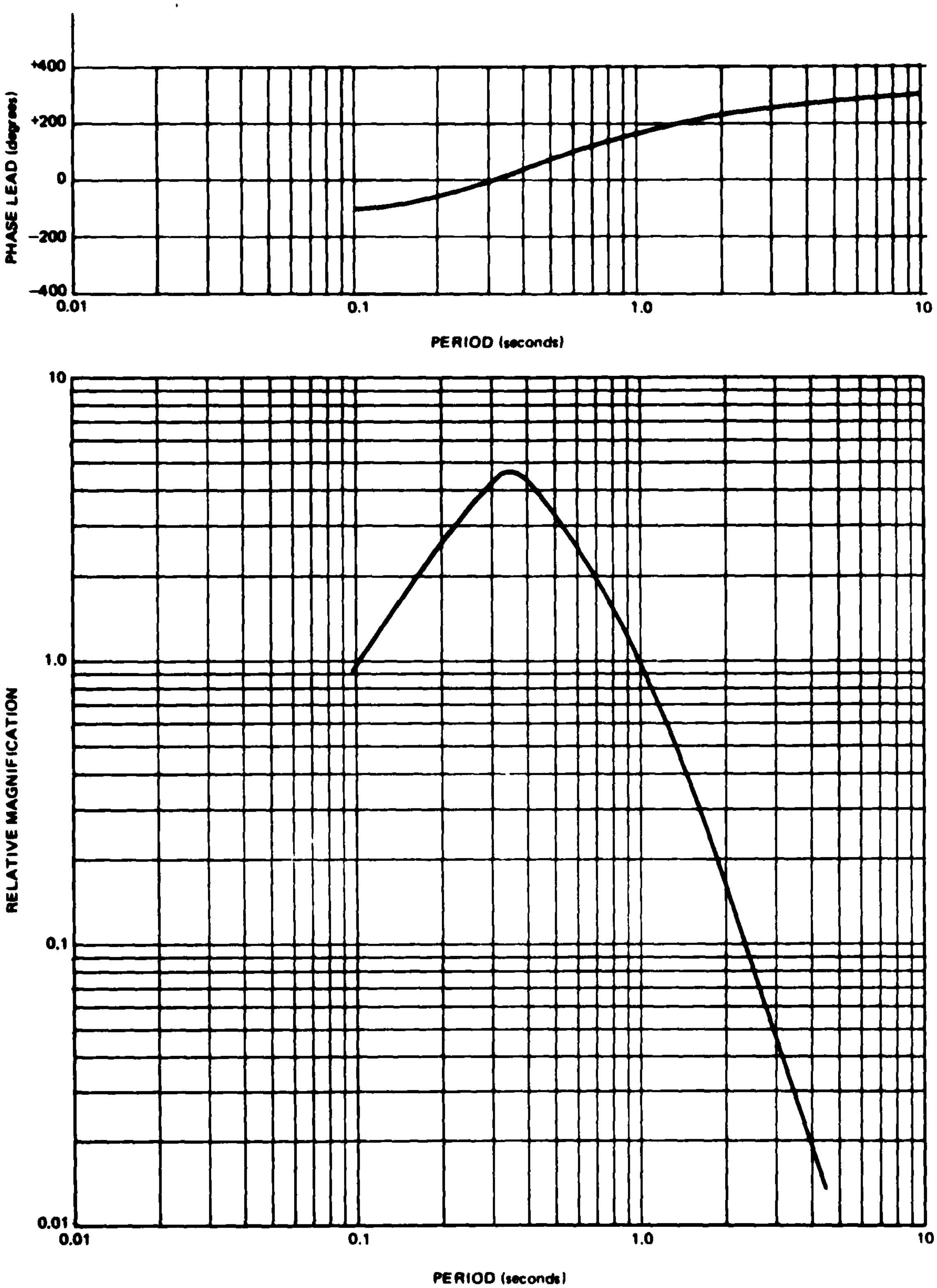


Figure 3. Theoretical amplitude and phase responses of the short-period seismographs in the Portable Seismograph System, Model 19282A, as used at sites RB-CO, OB4NV, RU-CO, and BJ-NV

G 8243

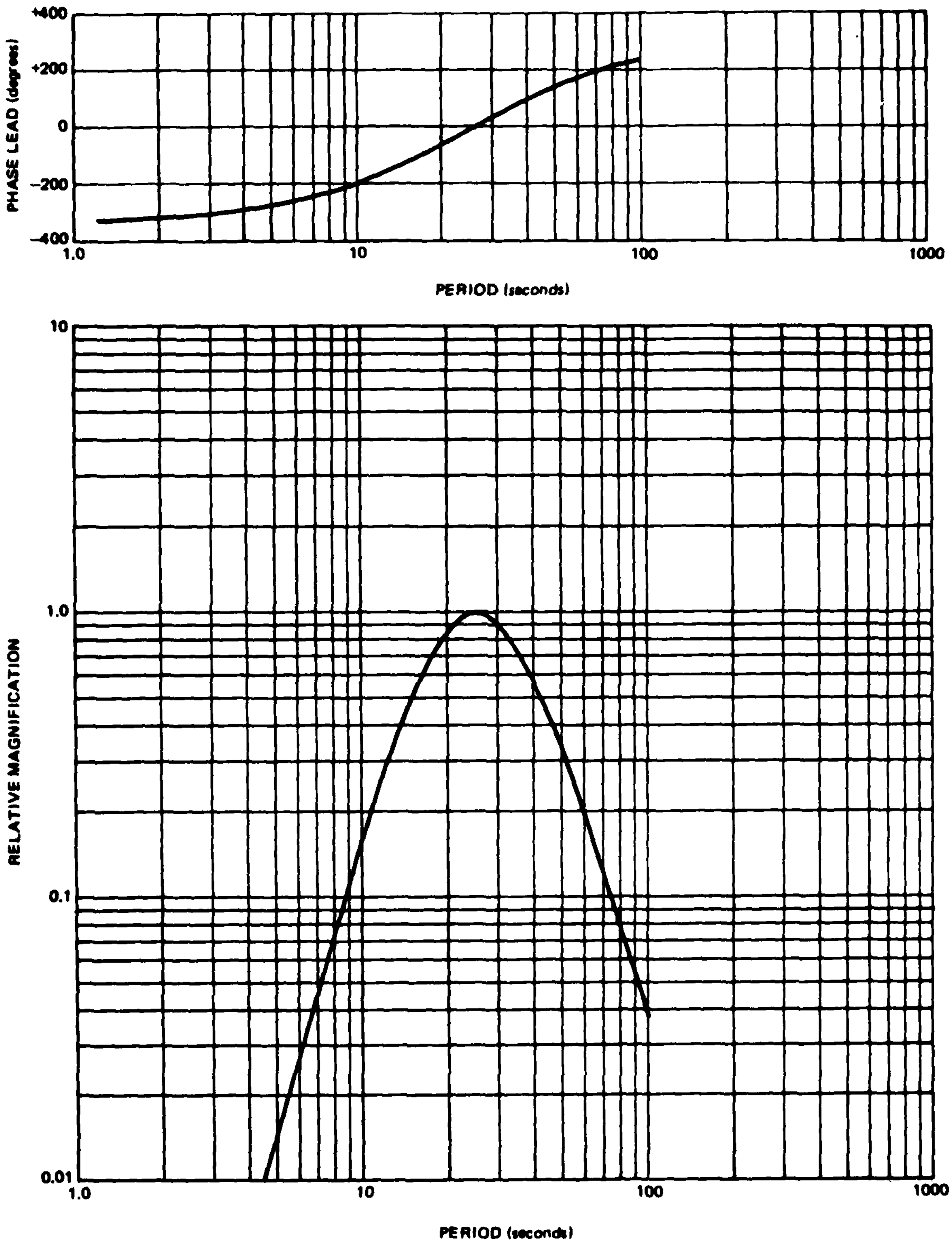


Figure 4. Theoretical amplitude and phase responses of the long-period seismographs in the Portable Seismograph System, Model 19282A, as used at the BJ-NV site.

G 8244

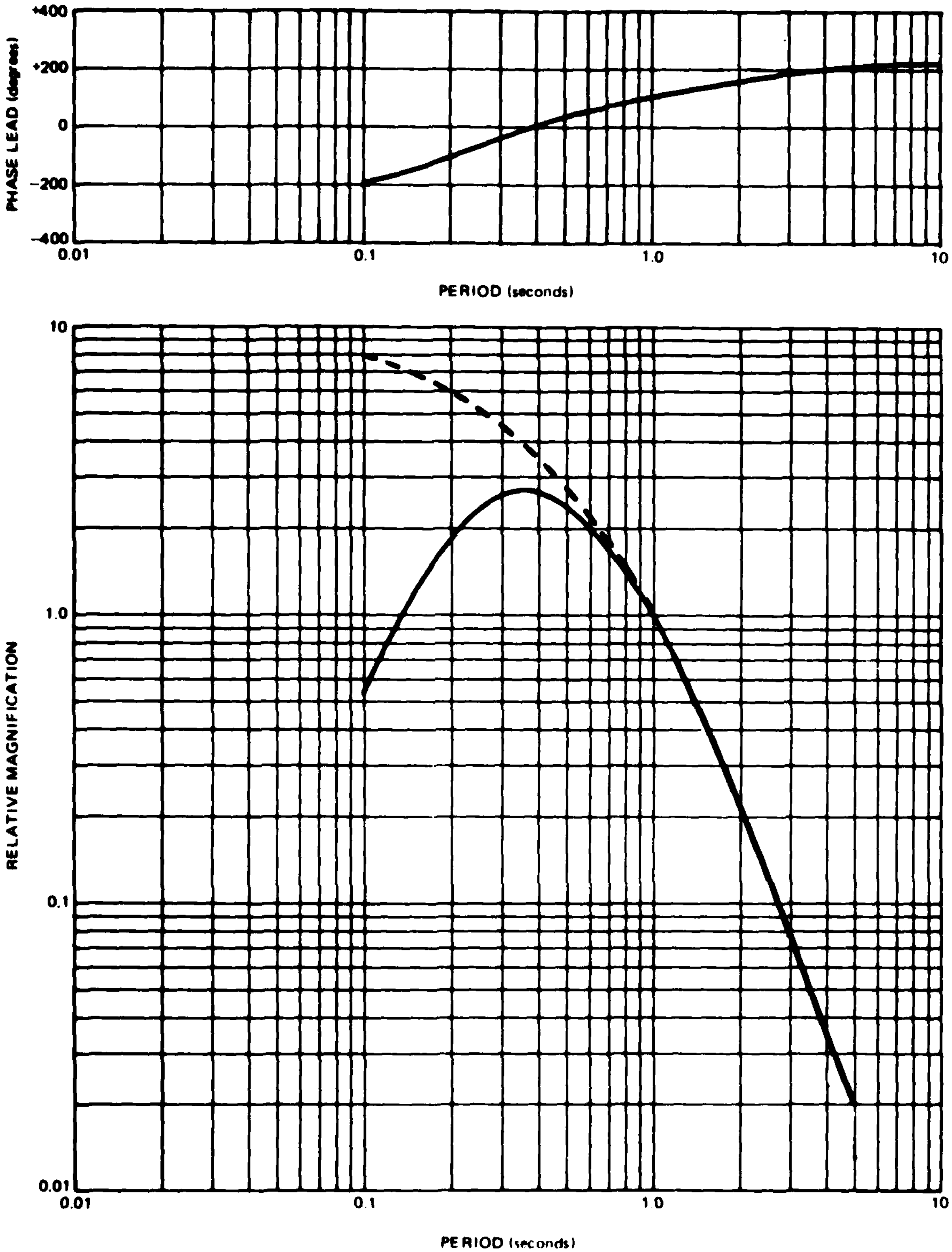


Figure 5. Theoretical amplitude and phase responses of the KS36000 short-period seismographs at Cumberland Plateau Observatory

G 10691

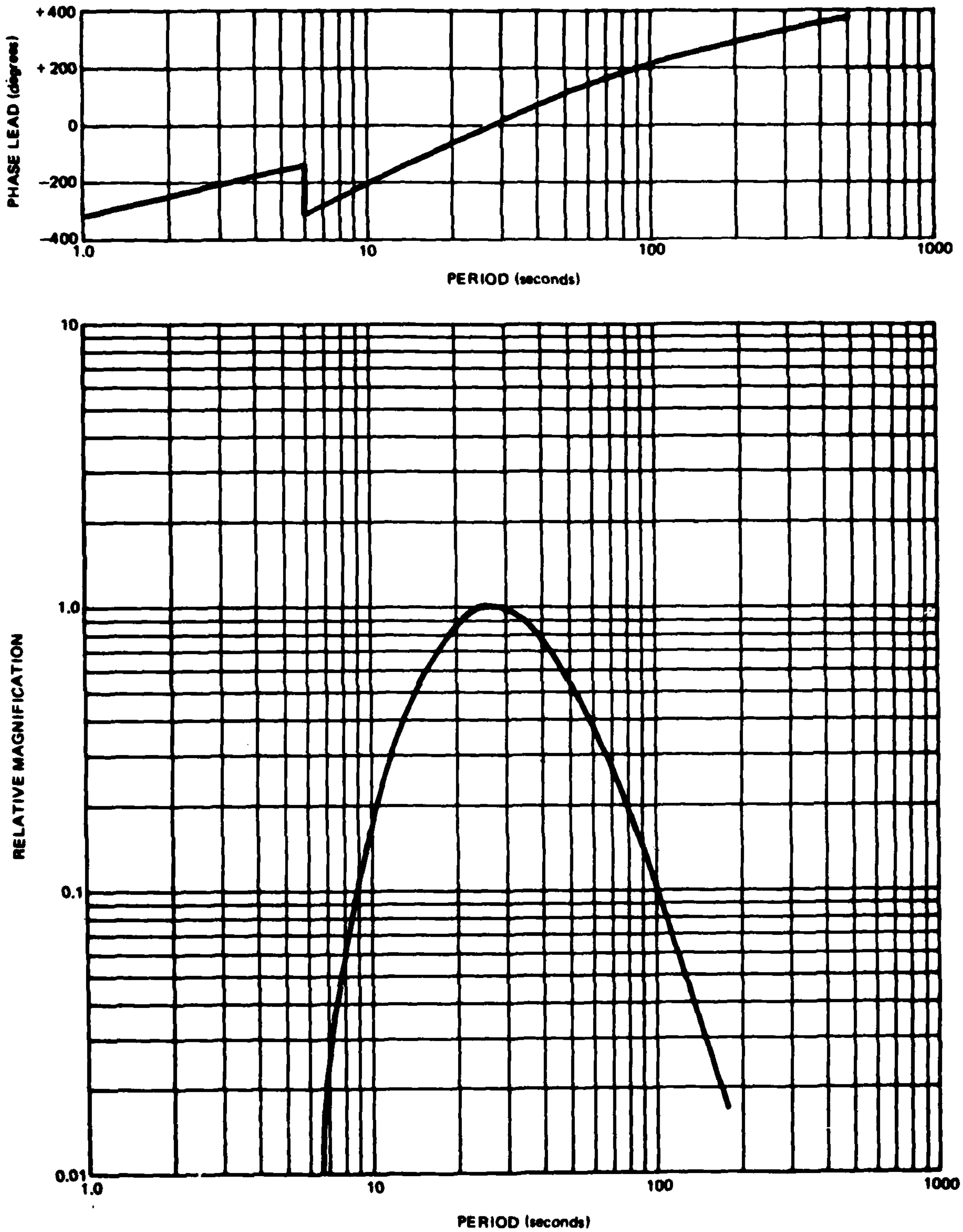


Figure 6. Theoretical amplitude and phase responses of the KS36000 long-period seismographs at Cumberland Plateau Observatory

G 10692

graph 1
3 x 3

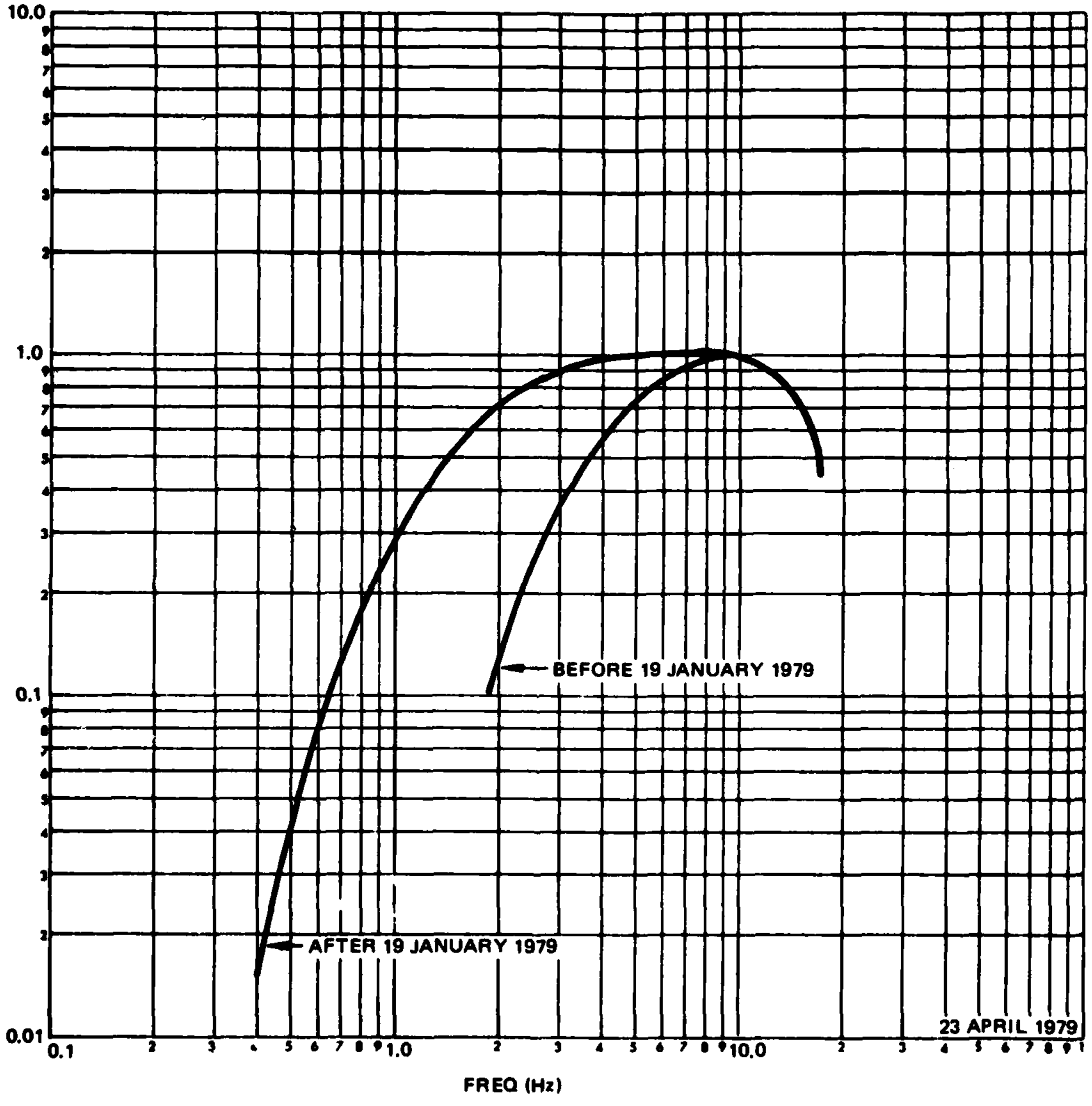


Figure 7. Displacement response of HFZ at McKinney, Texas

G 10693

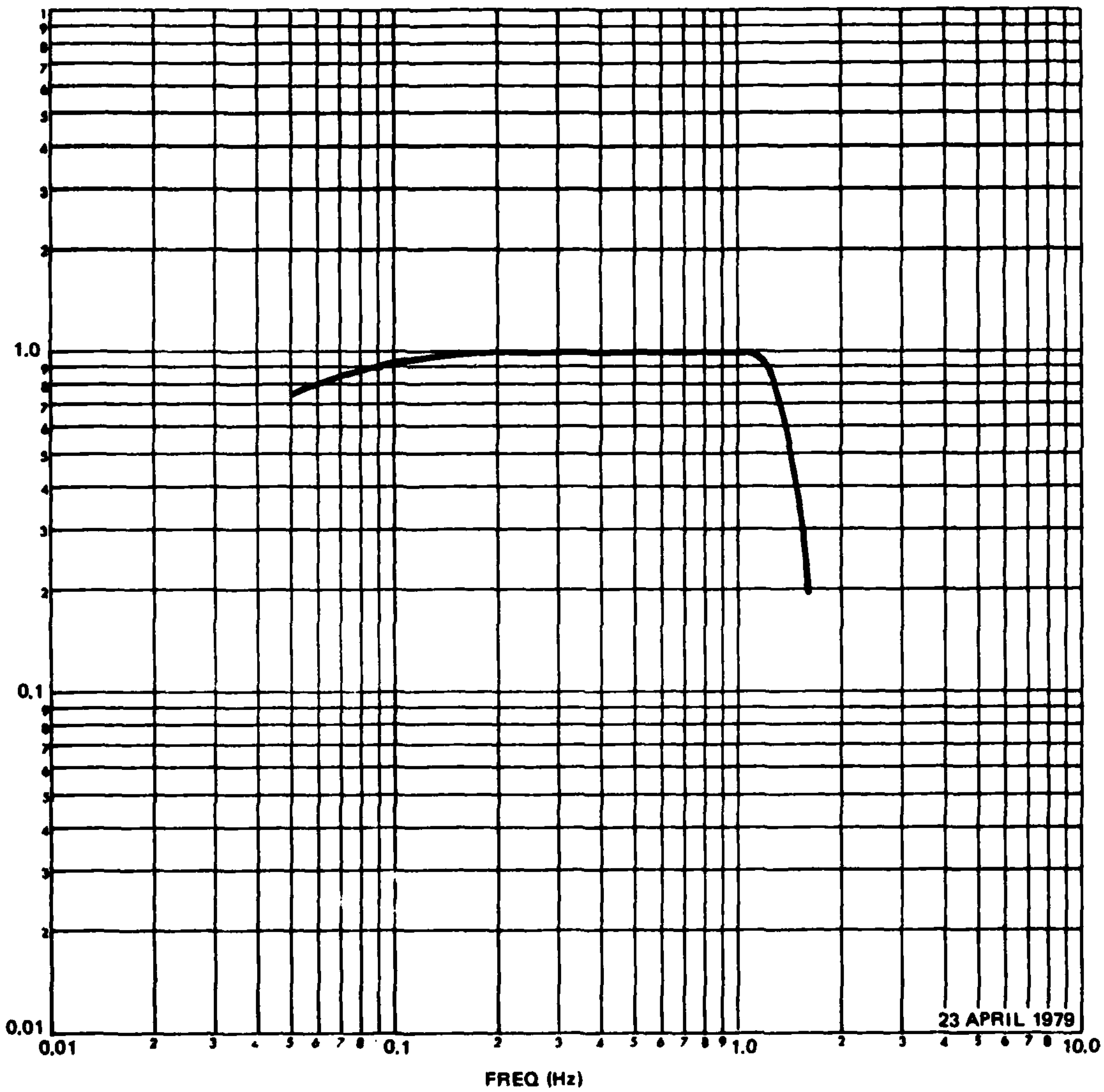


Figure 8. Velocity response of MCK intermediate period seismographs

G 10694

RECORDED ONCE PER RECORD

9 TRACK	CHANNELS SELECTED		OP CODE	TEAM NO.		YEAR	TIME FROM EXTERNAL TIMER				22 BYTES ZERO		1ST SAMPLE		2ND SAMPLE		1008TH SAMPLE	
PARITY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
0	1	1	1	1	1	1	200d	2d	0	0	0	0	0	2^7	0	2^7	0	2^7
1	1	1	1	1	1	1	100d	1d	40m	40s	0	0	0	2^6	0	2^6	0	2^6
2	1	1	1	1	1	1	80d	20h	20m	20s	0	0	0	2^5	0	2^5	0	2^5
3	1	1	1	1	1	1	40d	10h	10m	10s	0	0	0	2^4	0	2^4	0	2^4
4	80	8	8	80	8	8	20d	8h	8m	8s	0	0	2^{11}	2^3	2^{11}	2^3	2^{11}	2^3
5	40	4	4	40	4	4	10d	4h	4m	4s	0	0	2^{10}	2^2	2^{10}	2^2	2^{10}	2^2
6	20	2	2	20	2	2	8d	2h	2m	2s	0	0	2^9	2^1	2^9	2^1	2^9	2^1
7	10	1	1	10	1	1	4d	1h	1m	1s	0	0	2^8	2^0	2^8	2^0	2^8	2^0
	1	2	3	4	5	6	7	8	9	10	11 ...	32	33	34	35	36 ..	2047	2048

INTER RECORD GAP OR BEGINNING OF TAPE

INTER RECORD GAP

TAPE CHARACTERS (BYTES)

TAPE MOTION ←

NOTES:

1– 2^0 IS THE LSB.

2– DATA FORMAT NOT PHYSICAL DATA LOCATION ON TAPE (EBCDIC CODING).

3– 2048 CHARACTERS PER RECORD.

Figure 9. Digital tape format - typical SDCS operation

G 8811

For the MCK operation, the system interrupt format was changed to allow collection of one channel of HF data at 60 sps and three channels of IP data at 6 sps. In order to preserve the feature of an integral number of seconds in each 2048 byte record, the number of zero-filled bytes in the header was reduced to ten instead of 22 as shown in figure 9. The system is also capable of recording in a standard, sequential format where all channels are sampled at the same rate. In this case, there are no zero filled tape bytes. This mode of operation was used briefly at MCK to collect two channels of HF data at 60 sps, one from the KS36000 system, and one channel from a standard inertial seismometer installed in a surface vault. For all configurations, channel assignments and operating modes are documented on operational logs which accompany each tape record.

The digital recording system can be readily adapted for other operations as required. For more complete details, refer to the manual for this system.

2.3.3 Operating Characteristics of the Analog Magnetic Tape System, Model 19429

The Analog Magnetic Tape System, Model 19429, is routinely operated at all standard SDCS sites. For those stations equipped with digital recorders, the analog system is used for backup. For all stations, the analog tape data are also used by support personnel to monitor data quality and to identify any operating problems for the field operators. The system records a one-inch magnetic tape at a speed of 0.03 inches per second; a standard 2400-foot reel of tape is used which is usually changed every seven to ten days. The system records 13 channels of IRIG compatible, frequency modulated data and one direct record channel for VELA time code. As with the digital recording, each analog tape record is accompanied by an operational log which indicates channel assignments and any special configurations for that record.

3. ENGINEERING SUPPORT

The engineering support function in Garland routinely provides for control of government property and replacement or repair of parts for SDCS operations. In addition, changes to system hardware are developed to improve operation or to correct deficiencies. In the following paragraphs, engineering support activities during this period are discussed.

3.1 DIGITAL RECORDING SYSTEMS

The five digital recording systems were operated routinely during the reporting period. Most of the systems functioned without major problems, but one system (at RB-CO) was inoperative for about two months due to several factors. The first problem was lightning damage on two occasions which resulted in damage to both the original and a spare printed circuit board assembly in the Pertec tape deck. These units were returned to Garland for repairs. Damaged components were isolated, but completion of repairs was further delayed by long delivery times of replacement parts. Finally, the station operator with limited time, experience and test equipment had difficulties in locating other malfunctioning components.

As a result of this experience, new procedures were developed for future digital system problems in the field. First, failures were analyzed and it was determined that the supply of m ajor subassemblies was adequate, provided that a rather complete supply of individual components was maintained in the laboratory. Also, repairs to inoperative assemblies would be completed in the laboratory as soon as possible after return from the field. Finally, an engineer would be sent from Garland to restore a system to operation if the station operator could not resolve a problem quickly by replacing subassemblies. These procedures were later used at the OB4NV site, and downtime was greatly reduced.

The failure history at the end of the reporting period indicates that the Pertec tape decks are responsible for most of the system failures, despite the fact that routine preventative maintenance procedures are performed according to the manual for the unit. It is suggested that these units be returned to the manufacturer for complete checks and refurbishing before attempting any long-term operations in the future. Other subassemblies of the system, including the Kinemetrics DDS-1103 electronics drawer and the Geotech interface unit, have been very reliable; and no particular problems are anticipated for future operations.

At the close of this program, three of the systems had been checked, repaired as necessary, and returned to storage. One system was on loan to another program, and the fifth unit had been officially transferred to the Seismic Data Analysis Center (SDAC) contract.

3.2 SUPPORT OF SDCS STANDARD HARDWARE

3.2.1 Time Recording on FM Magnetic Tape

All SDCS stations record standard format VELA time in binary-coded decimal (BDC) form on channel 14 of the FM magnetic tape system. This BCD time is used during processing for tape search and event timing. During this period a study was made to determine the causes of variable and intermittent BCD signal levels from several field sites. It was determined that such fluctuations could be caused by poor quality or damaged tape, misadjusted tape tension across the record heads, or improper electronic drive levels. Tape tension was found to be the single most significant factor, which was easily corrected by simple adjustments. To prevent future instances of slow deterioration of the quality of time code recording, procedures were developed to regularly check tape tension and to make any adjustments necessary.

3.2.2 Calibration Equipment Modifications

The Control Monitor, Model 19823, is used to perform magnification calibration for the SDCS system. During this reporting period, procedures were developed to correct a wiring error in all these units which was discovered at the TQ-MS site. The problem was that the calibration circuit was improperly grounded, which placed the seismometer calibration coils at several volts above ground during calibration; even minor calibration-to-data circuit leakage caused severe crosstalk. A modification memo was sent to all teams; and all units were subsequently modified, including those in storage at Garland.

3.2.3 Checkout of SDCS Units Returned from the Field

All SDCS units returned from the field are thoroughly tested and repaired as necessary before returning them to storage. The warehousing policy in the past has been to store complete systems, including tools, equipment, cables, etc., in large crates in order to facilitate gathering of equipment for later deployment. However, due to the nonstandard nature of the recent SDCS operations, this technique has lost many of its original advantages. As a result, storage methods were changed as equipment recently returned from the field was placed in the warehouse. Equipment was grouped by function rather than by team for greater visibility and ease of accounting. In accordance with the provisions of the contract (and the expected follow-on program), no maintenance is to be performed on stored equipment, nor is any equipment to be removed from the warehouse without the permission of the Project Officer.

At the close of the program, all the various modules of the eleven portable systems had been placed in storage, along with several items of special-purpose laboratory equipment. Exceptions were items and components susceptible to damage by temperature extremes (such as magnetic tape heads) and several items on authorized loan to other programs.

3.2.4 Improved Amplifier and Control Unit, Model 52280

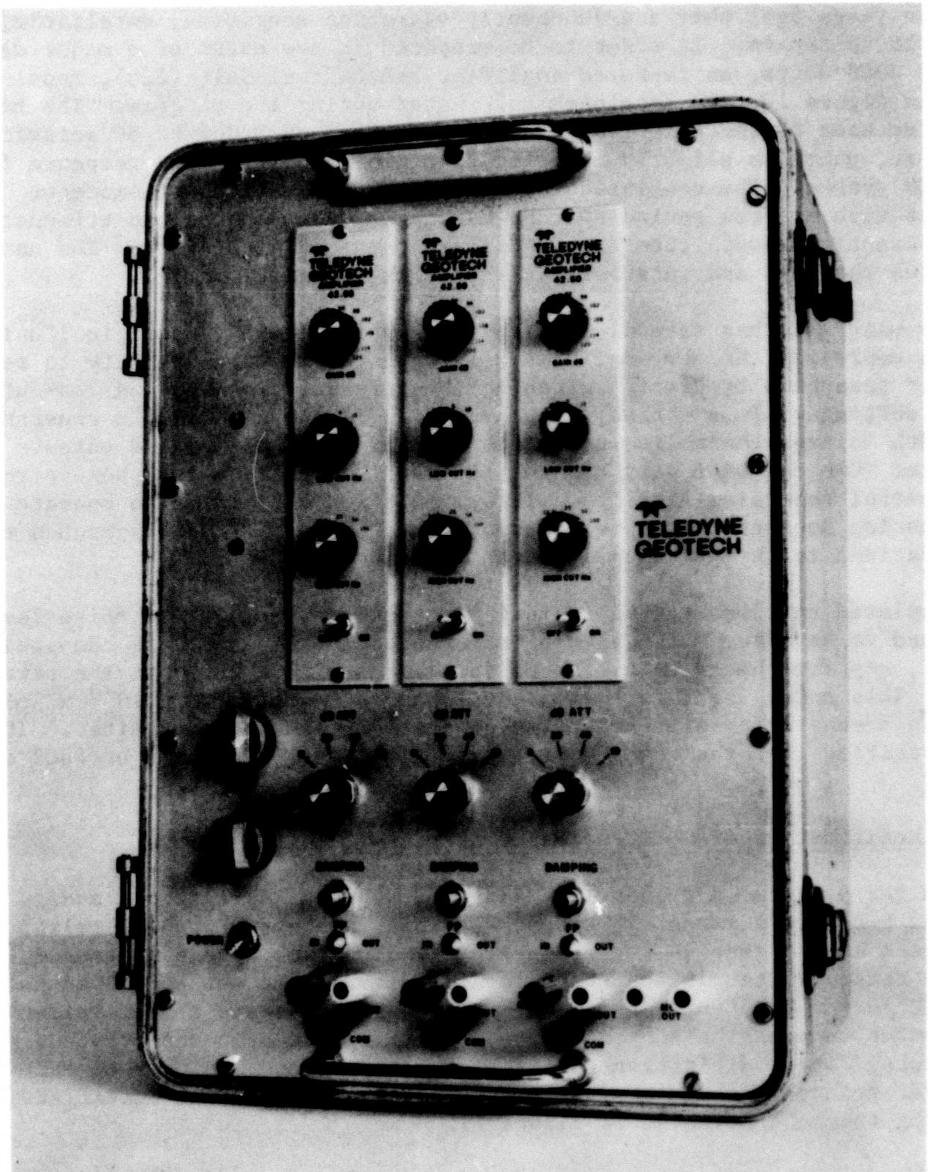
The five older SDCS units use photocell amplifiers in their short-period systems. These units have deteriorated significantly since they were built over ten years ago; they are inherently vibration sensitive, unreliable, and difficult to repair. In order to be prepared in the event of a major deployment of SDCS units, an improved Amplifier and Control Unit (ACU), Model 52280, shown in figure 10, was developed and tested during the program. The basic amplifier used is the relatively inexpensive Geotech Model 42.50 seismic amplifier, which is slightly modified to achieve the required response for the SDCS system. The completed unit also includes various seismometer controls such as free period switch, damping adjust control and attenuator which essentially duplicate the functions of the original unit. The unit also uses the case and internal cabling of the original device.

The new unit also has several features not available in the original unit. Systems employing the new amplifier will have increased capability to record in other passbands by simply switching to different high-cut and low-cut filter settings. In addition, each amplifier is supplied with a constant bandwidth voltage controlled oscillator (VCO). The multiplexed outputs of the three VCOs can be easily transmitted over voice-grade telephone circuits to a central recording facility. This will allow SDCS units to operate short-period sensors at remote locations and will significantly reduce costs in comparison to that of manned sensor locations.

The completed unit was tested to verify proper operation. The noise level was found to be about 0.65 μV, p-p (referenced to the input) as compared to 0.25 μV, p-p for the high-quality solid state amplifier used in the newer SDCS units. This noise level is equivalent to approximately 0.3×10^{-9} m, p-p which is adequate for all except the quietest of short-period sites. The tests verified that the new ACU will meet all the requirements of SDCS operations.

3.2.5 Modification of SDCS Frequency Response

Late in the program, a request was made and approved to slightly modify the SDCS short-period seismograph response. This change reduces the relatively sharp peak in the response at approximately 3 Hz (see figure 3) caused by a lightly damped filter in the standard ACU. The change was sought to match the SDCS response to most "standard" responses in use and also to allow a close match between the ACU and the new unit discussed in the previous paragraphs. The modification consists of changing one resistor on each amplifier printed circuit card. Components were ordered and installed. The resulting response is shown in figure 11.



Amplifier Control Unit, Model 52280

P- 19759

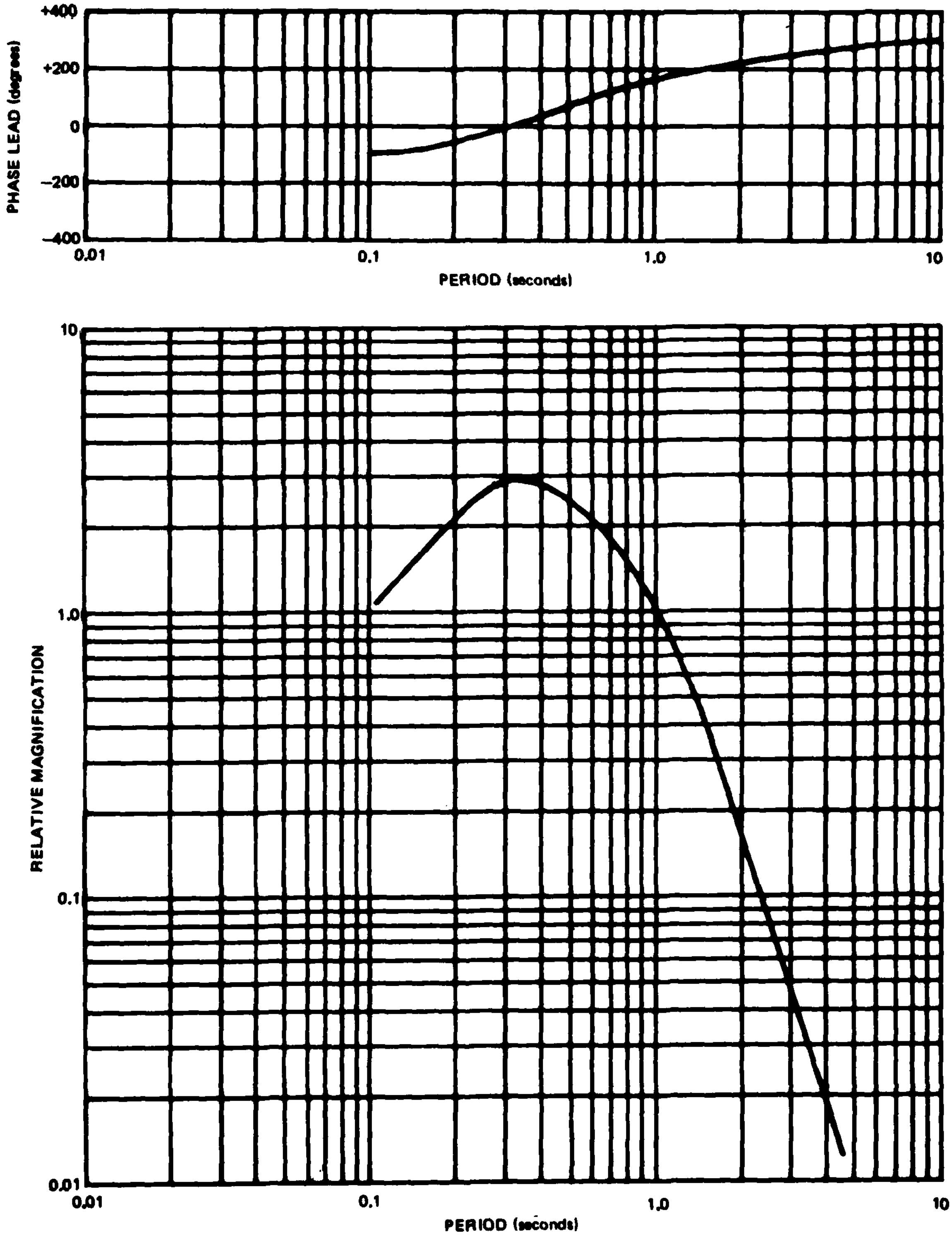


Figure 11. Theoretical amplitude and phase responses of the short-period seismographs in the Portable Seismograph Systems, Models 19282 and 19282A; modified Sept 1978

G 8243A

3.3 KS36000 SYSTEMS

The SDCS program has three KS36000 borehole seismometer systems assigned. During this program, system S/N X001 was operated at HN-ME through August 1978 after which it was returned to Garland for minor repairs and retest. The system was then operated at CPO from March through May 1979. During all operational periods, the system proved to be exceptionally reliable. This system was subsequently returned to the warehouse where the other two units remained throughout most of the period.

Associated support equipment for the KS36000 systems is also available in the SDCS inventory, including cables, winches, masts, borehole seals, holelocks, etc. Filter units to provide the short-period and long-period seismograph responses are also available. Two units are prototypes built for a test series in 1974. These units continue to perform adequately but should be replaced with standard units if extensive KS36000 operation is scheduled for the future. The third unit is standard but includes long-period filters only.

3.4 SDCS SUPPORT FOR OTHER PROJECTS

The SDCS program has routinely supplied equipment on a loan basis to support other government projects as directed by the Project Office. During this period, equipment was provided to the 1155th TCHOS to verify the effectiveness of hardware items designed to allow operation of the KS36000 sensor in a large (11-3/4 in.) diameter borehole. The following equipment was supplied from November 1977 until April 1978:

Borehole Seismometer System, Model 36000, S/N 004	1 each
Cable, Type 12J46SB	800 feet
Filters, Short-Period, Model 38850	3 each
Cyrosurveyor Probe System, Humphrey Model GP07-0901	1 each

In shipping the equipment back to Garland, the three SP filters were lost; but all other items were received and returned to storage.

The project to develop the Model 44000 Borehole Seismometer System was also supported in Garland with various items of equipment to filter and record test data, along with borehole support equipment. Such equipment will continue to be furnished during the course of this development program which was still in progress as the SDCS program ended.

In early April, the gyrosurveyor probe system, used to determine the orientation of KS36000 holelocks, was transferred to the 1155th TCHOS for an indefinite period.

Finally, several items of SDCS SP equipment were on authorized loan to ARPA/OSR, Contract No. F49620-79-C-0015 for a program to study the characteristics of high-frequency seismic data. Items include:

SP Seismometer, Model 18300	6 each
Amplifier/Control Unit, Model 29460	2 each
Timer/Programmer, Model 19754A	1 each
Digital Recording System, Model 43419	1 each

These items are to be returned in December 1979.

4. DATA PROCESSING

The data processing tasks under this contract include routine analog tape quality control and special playouts of data as required. Digital tape quality control and event processing tasks were performed in Alexandria, Virginia, under the SDAC contract.

4.1 QUALITY CONTROL OF THE ANALOG TAPES AT GARLAND

Portions of the analog tape records were played out on 16-mm film for use as a quality control check of the field data. Approximately 24 hours of data from each 10-day tape were reproduced with the film recorder operated at six times short-period (SP) film speed (180 mm/min) and the tapes reproduced at 20 times real-time (0.6 ips). The resulting film presentation is a compression of the SP data by 3.33 as compared to normal SP films, but the resolution has been found to be adequate. The film data were viewed in Garland prior to shipment to the SDAC. The films proved to be a valuable aid in detecting symptoms of potential system troubles not readily identified in the field.

4.2 QUALITY CONTROL OF DIGITAL TAPES

The quality control and event processing of SDCS digital tape records is the responsibility of the SDAC in Alexandria, Virginia. During this report period, no quality control functions were performed, resulting in records of unknown quality. It is strongly recommended that the quality control program be given a high priority if the digital data from SDCS sites are to be effectively utilized as the operator has no completely effective check on the quality or reproducibility of his records.

5. SPECIAL PROJECTS

5.1 EVENT DETECTOR FOR THE SDCS DIGITAL RECORDERS

Work on the previous contract demonstrated that a signal detection algorithm based on one developed by USGS would be useful for the SDCS digital recorders. Such a system would decrease tape usage at the field sites and would eliminate the overtime which has been necessary to change digital tapes seven days per week. With the approval of the Project Office, a program to develop such a unit was begun in October 1977.

Preliminary specifications and programming were completed in early November for the microprocessor-based event detecting circuit. Because the algorithm is complex, the circuitry required to implement it was considerably more extensive than originally anticipated. For example, it was determined that a separate microprocessor would be required for each channel to be processed (three were envisioned), and another would be required to control the subsystem. When this complexity was determined, the circuitry of the Kinemetrics DDS-1103 digital recorder was studied in detail. This study showed that the DDS-1103 control circuitry would not be easily adapted to that of the event detector. It was also found that continuous recording of the long-period samples while routing SP data through the event detector would be an expensive task. Therefore, efforts under this project were suspended.

5.2 DEVELOP LOW COST METHODS FOR SHORT-PERIOD BOREHOLE SEISMOMETERS

During September 1978, work was begun to develop methods of reducing the cost of short-period borehole installations. Because the boreholes themselves are the greatest cost factor, especially at remote locations, emphasis was placed on developing techniques using relatively low-cost, portable drilling units and low-cost casing materials. Initial studies indicated that the limited hole diameter capability of such rigs would likely require a smaller instrument than the 3.75 inch diameter Model 23900 now in wide use for these installations. Work under tasks 4.6 and 4.7 was thus a two-phase program to (1) develop techniques using low-cost, lightweight plastic casing for shallow boreholes and evaluate them and (2) develop a borehole package for an existing low-cost small diameter seismometer.

During discussions with the selected drilling rig manufacturer early in the program, it was determined that such rigs could be modified slightly to drill holes large enough to accommodate a more conventional seismometer, the Model 20171A. Because this unit was already designed and a more familiar construction and because its use would result in a lower overall noise level, it was decided to abandon the work to package the unproven, low-cost seismometer. Effort was then redirected to the task of evaluating plastic-cased boreholes.

In late November, two shallow boreholes were drilled at the Geotech facility and cased with 4.5-inch outside diameter plastic (PVC) pipe. Model 20171A seismometers were installed in the boreholes in December, and a Model 18300 instrument was installed at the surface for comparison purposes. The responses of the three seismographs were carefully adjusted for a close match and data were recorded until mid-January on a Develocorder. Subsequent visual analysis of the data showed that the PVC-cased boreholes performed properly and did not adversely affect the operation of the borehole seismometers. The program showed that there are disadvantages to use of PVC pipe, particularly if problems arise in installing it in the open boreholes. The tapered, glued joints are subject to failure if too much force is exerted and make retrieval of the casing difficult if the need arises, such as in the instance when an obstruction is encountered.

The results of this study were reported in detail in Technical Report No. 79-1, Final Report, Tasks 4.6 and 4.7, Contract F08606-78-C-0011.

5.3 SITE SELECTION MANUAL

In early July 1979, a simulated site selection exercise was conducted on a granite outcrop in southern Oklahoma. This exercise formed the basis of the site selection manual which was prepared under Task 4.8 of the contract. The delivery of the completed manual, Technical Report No. 79-11, Seismic Site Selection, was made on 31 July 1979.